

FEED PLATE FOR A FUEL CELL WITH COPLANAR CIRCULATION**Field of the invention**

5 The invention concerns the area of fuel cells that
are composed of a stack of a large number of stages,
each including a basic element which in turn is
composed of a separating membrane placed between two
electrodes, themselves placed between two polar or
10 bipolar plates.

This type of fuel cell can find its application in
many areas of activity, including in both military and
civil sectors. The military applications include, in
particular, underwater propulsion, mobile electric
15 generators and low-power units as a replacement for
batteries. The military or civil applications include,
amongst other things, the transportation area, for the
propulsion of urban public transport vehicles for
example, such as buses, trams, trolley buses and so on.
20 Applications for motor vehicles, trucks and trains are
also envisaged. Other stationary applications are also
possible, in particular on stationary systems for the
local production of electricity, like those used in
hospitals and others service buildings where the
25 possibility of an interruption to the electrical power
supplies must be excluded. Finally, other potential
applications exist in the area of the portable and
miniaturised devices.

Prior art and the problem posed

The fuel cell is an electrochemical device which converts the chemical energy of a fuel, of the renewable type in certain cases, into electrical
5 energy. The operating principle of this electrochemical generator depends on the reaction of electrochemical synthesis of water. Many fuel cells are composed of a succession of stages, each including a basic element composed of two electrodes, one an anode and the other
10 a cathode, to which are continuously supplied an oxidiser, such as oxygen from air, and a fuel such as hydrogen, which remain separated by an ion-exchange membrane acting as an electrolyte. At the anode, the fuel undergoes catalytic oxidation which, in the case
15 of a fuel cell of the proton exchange membrane type, releases protons and electrons. The electrons travel along the external electrical circuit, while the protons are transported in the electrolyte to the cathode, where they recombine with the electrons and
20 the fuel, under the effect of catalytic reduction to produce water. These two operations are accompanied by the establishment of a potential difference between the two electrodes.

The efficiency of the fuel cell, in theory
25 slightly less than 100 %, reaches values greater than those of the internal combustion engine. Moreover, the fuel cell is quiet and virtually non-polluting, even though the fuel is an organic compound. This high efficiency, and the low production, are some of the
30 reasons for research and development in this area.

The various types of fuel cell can be defined by the nature of the electrolyte constituting the membrane. One of the most advanced types of fuel cell in the temperature area below 100°C is that of fuel
5 cells with a polymer electrolyte. This present invention relates to the area of fuel cells of the PEM type (proton exchange membrane), in which the electrolyte is a proton exchange membrane.

Mechanically, the fuel cell is composed of a stack
10 electrochemical cells constituting a stage, each cell being composed of polar or bipolar separating plates between which a basic EME element (Electrode, Membrane, Electrode) is sandwiched. Such an arrangement of basic cells constituting the core of a fuel cell is known by
15 those skilled in the art as a "stack".

In a stack of fuel cells of the PEM type, the separating plates, called bipolar plates, also perform the function of reagent gas distribution, composed of oxygen or air and hydrogen, as well as collection of
20 the electrons produced, and removal of products of the reaction, in particular the water. Each bipolar plate is in contact, at one of these faces, with an anode of a basic element N, and at the other face with a cathode of a basic element of rank N+1.

25 Finally, in high-power fuel cells, a last function of these polar or bipolar plates is the refrigeration of the whole stack by the circulation of a coolant liquid between the different basic cells of the fuel cell. The coolant fluid flows in channels which are
30 specifically designed and integrated into the polar or bipolar plates. It can be seen that this refrigeration

may not be applied to all the stages, but rather in a periodic manner in the stack.

The French patent application published under the number FR-2 810 795 describes a bipolar plate which 5 performs the distribution of the oxidiser and the fuel to its two faces by means of two circulation channels. At the middle of the skeleton of this bipolar plate, between two metal plates, the circulation of the coolant fluid is organised. These bipolar plates have a 10 substantial thickness due to the design, which requires that the circulation, firstly of fuel and oxidiser and secondly of liquid coolant do not interfere. This is why they are placed in different respective planes.

The thickness of this bipolar plate, like those of 15 many other cells, is therefore high.

The objective of the invention is to remedy this drawback by proposing a different type of polar or bipolar plate.

20 **Brief description of the invention**

To this end, the principal subject of the invention is a feed plate to at least one cell of a fuel cell, that includes:

- apertures for the feeding of fuel, oxidiser 25 and coolant fluid;
- two opposite faces on at least one of which there are channels for circulation of the fuel or the oxidiser; and
- at least one refrigeration channel located on 30 the same face or faces as that or those on which the channels for circulation of the fuel or oxidiser are

located, so as to be coplanar with these circulation channels, where the feed plate thus has a minimalised thickness, and with the refrigeration taking place at the heart of the active area. It is therefore more
5 effective.

According to the invention, the first channels for respective circulation of the fuel and oxidiser are located on the two faces of the plate, with the refrigeration taking place on both faces of the plate,
10 when the plate thus constitutes a bipolar plate, with a single refrigeration channel being located on both faces at once and, as a consequence, having several passages through the plate from one face to the other, as well as branches.

15 In the main embodiment of the invention, the entrance and the exit of the refrigeration channel is placed on the face opposite to that where this refrigeration channel is located, with the latter passing through the thickness of the plate.

20 It may prove advantageous to group together the apertures for feeding the oxidiser, fuel and coolant fluid and the entrances and exits of the circulation and refrigeration channels in one set position on the plate.

25 Concerning the sharing of different channels on the face or faces of the plate, it can be arranged that the trajectories of the circulation channels and of the refrigeration channel or channels should be interleaved in relation to each other, thus following the same
30 path.

A preferred trajectory of the circulation channels of the plate according to the invention is designed so that the latter is a zigzag path.

Concerning the trajectory of the circulation channels, it is also possible that these should be parallel to each other, so as to form a comb-like structure.

In a preferred embodiment of the refrigeration channel or channels, the latter have branches whose entrances and exits are spaced over much of the length of the plate.

A particular feature of this implementation may be that the orientation of the channels should be offset by 90° at one face in relation to the other.

In these latter cases, it is arranged that the passage through the plate by the refrigeration channel takes place at the end of each branch, with a change of orientation of 90° for the refrigeration channel at the passage through the plate.

In one particular embodiment of the plate according to the invention, the latter takes the form of a corrugated plate, so as to form first channels for circulation of the fuel on a first face interleaved with parallel refrigeration channels on a first face, and channels for circulation of the oxidiser interleaved with parallel refrigeration channels, so that the channels on the first face form separations for the channels on the second face and vice versa, with all the channels located in the same plane, and with the plate then constituting a bipolar plate.

In this case, the plate is composed mainly of a corrugated sheet possibly surrounded by a frame which is pierced by feed apertures.

5 In different embodiments, it is arranged that that the refrigeration channels or their branches are placed between several channels for circulation of the oxidiser or fuel.

10 In a method of operation of the fuel cell using the plate according to the invention, the coolant fluid is preferably water.

In a preferred embodiment of the plate, the latter is made from a polymer-graphite composite material.

The figures

15 The invention and its various technical characteristics will be better understood on reading the following description, with reference to figures which show:

- figure 1, in perspective section, one example 20 of embodiment of the feed plate according to the invention;

- figures 2A and 2B are two diagrams representing the layout of channels on a feed plate according to the invention, as shown in figure 1;

25 - figures 3A and 3B show the channel layout in a second embodiment of the feed plate according to the invention; and

- figure 4, again in perspective, shows one particular embodiment of the plate according to the 30 invention.

Detailed description of one embodiment of the invention

Figure 1 enables one to understand the design of the feed plate according to the invention by observing the cross-section of a preferred embodiment of this 5 plate. In this case, the latter is manufactured from graphite and, before the completion of its manufacture, has two plane faces which are machined during the manufacture of the latter so as to create the two faces, 1A and 1B.

10 A first face 1A has been shown in particular, though in part only. In fact, at the four corners of the latter there is a feed hole 2 or 3 for oxidiser or fuel. On this first face 1A, the oxidiser feed hole 2 feeds into an oxidiser circulation channel 21, where 15 this canal snakes over the area 1A so as to visit the largest central part of the latter. In addition, a coolant-fluid feed hole 4 is also placed at the periphery of the plate, and feeds into a refrigeration channel 41 running along the spaces left by the 20 oxidiser feed channels 21.

It can be seen that in most cases, the choice as to whether the oxidiser or the fuel should flow in one or other of the two faces is of no importance.

The second face 1B, is of similar design, but 25 oriented at 90° in relation to the orientation of channels on the first face 1A, which explains the dearth of channels shown on this second face 1B, because of the fact that the figure is in section. In fact, a second fuel circulation channel 22 has been 30 shown symbolically, but the latter is oriented in a direction perpendicular to its true orientation. A

branch 42 of the refrigeration channel 41 is shown at the centre of the plate and opens onto the second face 1B. This is fed at its two extremities by orifices 43 which cause it to communicate with the parts of the
5 canal 41 located on the first face 1A.

Referring to figures 2A and 2B, it is easier to understand the relative organisation of these two faces 1A and 1B. In fact, on figure 2A, the first face 1A of the plate is represented schematically. Here we see the
10 apertures for the feeding of oxidiser 2, fuel 3 and coolant fluid 4, as well as the oxidiser circulation channels 21, and the refrigeration channel 41. These circulation channels travel over most of the plate, executing one or more zigzags. At the middle of two of
15 these zigzags of opposite direction, are located the start and end of branches of the refrigeration channel 41, which lie parallel to the orientation direction of the circulation channels 21. It can be seen that these branches of the refrigeration channel 41 are equipped
20 with through holes 43.

Turning over the plate according to the invention, shown at figures 1 and 2A, we see the layout represented by figure 2B. However, the circulation channels 22 now concern the fuel, and connect the fuel
25 feed hole, at the entrance end, to the fuel feed hole 30 at the exit end. The feed apertures 2 and 20 are shown here in figure 2B, but are not connected to the first circulation channels.

It can be seen that the orientation of the zigzag
30 constituting the trajectory of these circulation

channels 22 is offset by 90° in relation to those on the first face 1A.

It can be seen that the branches 42, already shown on the face 1B of figure 1, are located between the 5 zigzags of the first circulation channels 22. At each of their ends, there is a through passage 43 which enables these branches 42 to be linked to the remainder of the refrigeration channel 41.

Figures 2A and 2B show a channel layout in zigzag 10 form, but by using the branches 42 of the refrigeration channel 41, it is possible to imagine that the trajectory of the circulation channels 22 may not be in zigzag form, but in the shape of a comb, with the different branches of the channel(s) 22 then being 15 parallel to each other and in relation to the branches 42 of the refrigeration channel 41.

The feed plate described with reference to figures 1, 2A and 2B, therefore allow the circulation of oxidiser and fuel respectively on its two faces. The 20 feed plate is therefore of the bipolar type.

With reference to figures 3A and 3B, it is possible that the feed plate may be only of the monopolar type. The example described by these two figures 3A and 3B shows that a single face, here face 25 51A, has only circulation channels 61. This same face 51A also has a refrigeration circuit in the form of a feed hole 54 for coolant fluid and two lateral refrigeration channels 53 with several branches 55, parallel to the parallel parts of the first circulation 30 channels 61 which run in the form of zigzags. The branches 55 each run in the space formed by a loop of

the zigzag run of the circulation channels 61, and in an alternating manner on either side of the plate. In this implementation, each branch 55 does one return trip over the width of the plate, passing through it at 5 its end 56.

Referring to figure 3B, it can be seen that the second face 52B has as its single canal the end and the exit of the refrigeration channel 53, in particular two branches 57 which allow it to be connected, by means of 10 through passages 58, to the other part of the refrigeration channel 53 on the first face 51A. Thus, the coolant fluid can be removed at the feed hole 59 placed at the periphery of the plate. In this case, the use of the different polar plates of a stack, imposes 15 alternation in the feeding of each plate with fuel and oxidiser.

It can be seen that in all of these cases, each plate is traversed by the three types of feed aperture, namely fuel, oxidiser and coolant fluid.

Figure 4 therefore represents one particular implementation of the feed plate according to the invention since the latter is composed, in the case of its central part, of a corrugated sheet 101. In this implementation, the corrugations are rectilinear and 25 parallel, but this shows only part of the corrugated sheet, and the circulation channels can in fact follow a sinuous or zigzag trajectory.

In fact considering each area 101S and 101I of the corrugated sheet, the corrugations form circulation 30 channels 102, 103 and 104 thus laid out in an alternating manner. In other words, the circulation

channels 102 formed on the upper surface 101S correspondent to the separations for two channels 103 and 104 formed on the lower surface 101I. In other words, the circulation channels alternate with the 5 corrugations which separate them.

In this figure 4, two first circulation channels 102 have been shown on the upper surface 1S. These have been assigned the role of fuel circulation channels, for the circulation of hydrogen H₂. In the case of the 10 circulation channels relating to the lower surface 101I, the figure shows, two first alternating channels for the circulation of oxidiser 103, that is for carrying oxygen O₂, with a second channel for circulation of the coolant fluid 4, which is water H₂O. 15 Likewise, shown on the upper surface 1S are some second channels for circulation of the coolant fluid 104, namely water.

This embodiment in corrugated sheet form means that the feed plate must be completed by a frame, which 20 is not shown in this figure 4, and which has apertures for the feeding of fuel, oxidiser and coolant fluid, in a manner similar to the preceding embodiments.

We have seen the use of a corrugated sheet in figure 4, this assuming the use of a metal for creation 25 of the feed plate according to the invention. However, one can well envisage such an implementation in expanded graphite.

The path of the trajectories of the circulation channels in all of the implementations take the form of 30 zigzags. However this is only one form of implementation, when the principle of the invention

concerns the placement of channels parallel to each other, and causing them to change direction in a parallel manner. It is thus possible to cover the major part of both faces of each feed plate according to the
5 invention.

In the embodiment of the invention, all of these circulation channels are located in the same plane. Moreover, the oxidiser, the fuel and the coolant fluid are all placed in direct contact with the basic EME
10 elements. In other words, no particular plane is reserved either to the refrigeration, or to the distribution of the fuel and oxidiser gases. On the contrary, just one single zone or layer performs the double function of distributing the oxidiser or fuel
15 and the coolant fluid. Moreover, by grouping together the entrances and the exits, it is possible to design two feed zones in the frame 20 where feed channels can pass to connect to the entrances and exits.